AD-A111 078 NAVAL RESEARCH LAB WASHINGTON DC F/G 20/6
PRELIMINARY LIDAR BACKSCATTER MEASUREMENTS.(U)
FEB 82 J A CURCIO, M A WOYTKO, D H LESLIE
UNCLASSIFIED NRL-MR-4742 NL

1 OF 1
AD A
111078

END
DATE
FILMED
03-82
DTIC

NRL Memorandum Report 4742

Preliminary LIDAR Backscatter Measurements

J. A. Curcio, M. A. Woytko and D. H. Leslie

Applied Optics Branch
Optical Sciences Division

February 19, 1982

NAVAL RESEARCH LABORATORY
Washington, D.C.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NRL Memorandum Report 4742	2. GOVT ACCESSION NO.: AD A11 3
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): PRELIMINARY LIDAR BACKSCATTER MEASUREMENTS	5. TYPE OF REPORT & PERIOD COVERED: Interim
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): J.A. Curcio, M.A. Woytko, and D.H. Leslie	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Research Laboratory, Washington, DC 20375	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62332N - ZF32392003; 65-1289-0-1
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Ocean Systems Center, San Diego, CA 95152	12. REPORT DATE: February 19, 1982
	13. NUMBER OF PAGES: 10
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

LIDAR
Aerosol backscatter

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Measurements of 1.06 μm LIDAR backscatter from hard targets, and aerosols are reported. Preliminary results are given, and on-going system improvements are described.

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

CONTENTS

PRELIMINARY LIDAR BACKSCATTER MEASUREMENTS

1. BACKGROUND

The work reported here represents the results of an initial NRL effort to use existing equipment to assemble a working LIDAR. The goal of the effort was to obtain both hard-target and aerosol backscatter signals, using existing NRL equipment. To this end the effort was successful. We report our methods, results, and equipment used. We also outline our plans for improving the system in FY-82.

Equation (1) is one form of the LIDAR equation[1] for describing the return of a laser pulse due to aerosol backscatter:

$$P_r\ (R) = P_t \times \frac{A_r}{R^2} \times L \times \beta\ (R) \times \exp\left\{-2\int_0^R \sigma\ (r)\ dr\right\} \tag{1}$$

where:

P_r = Power received at detector due to scattering at range R (watts)

P_t = Transmitted power (watts)

L = Laser pulse length (meters, $L = c\tau$)

$\beta(R)$ = Volume backscatter coefficient of the atmosphere along the laser path ($m^{-1}\ sr^{-1}$)

A_r = Area of the receiving aperture (m^2)

$\sigma(r)$ = Atmospheric volume extinction coefficient along the path to point R (m^{-1}).

We will discuss the application of Eq. (1) to return signals from hard-targets, and from aerosols in a smoke plume and rainfall. These measurements were performed at NRL's Chesapeake Bay Division. The LIDAR source and receiver were mounted in a trailer normally used in NRL transmissometer measurements.

2. EQUIPMENT

The lidar was assembled using existing NRL equipment. The source was a General Photonics 1.06 μm YAG laser. The laser output was 16 millijoules in a 30 nanosecond pulse, as shown in Fig. 1,

Manuscript submitted on December 15, 1981.

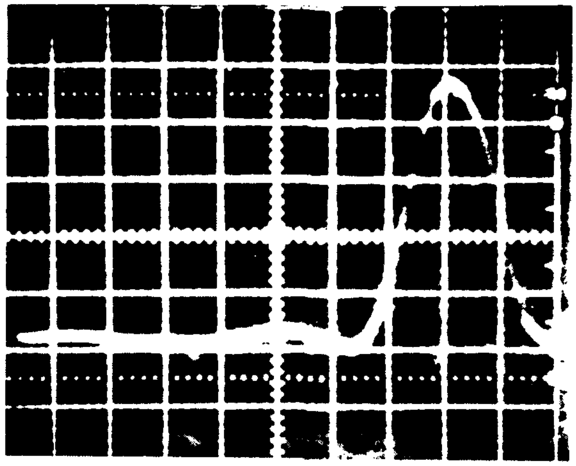

Fig. 1 — Oscilloscope Trace of Yag Laser Pulse (10 nsec per division)

for a peak of 5.3×10^5 watts. The laser beam divergence was 7 milliradians. The laser was mounted on the receiver barrel in a bistatic configuration. The receiver was a 24 inch diameter, $f/2.5$ telescope with a 6 milliradian field-of-view. The collector area was about 0.2 m^2 when the central obscuration was accounted for.

The detector was an uncooled S-1 photomultiplier. We had planned to use a fast silicon photodiode, but we were unsuccessful at obtaining noise-free operation. The probable source of the radiation noise is the laser power supply discharging circuits. We plan to eventually use a silicon photodiode, but in order to obtain some preliminary data we substituted an S-1 photomultiplier. This detector performed adequately, but as shown in Fig. 2, the S-1 response is far from optimum at 1.06 μm. A narrow band spectral filter centered at 1.061 μm was employed, and a trace of its transmission is given in Fig. 3.

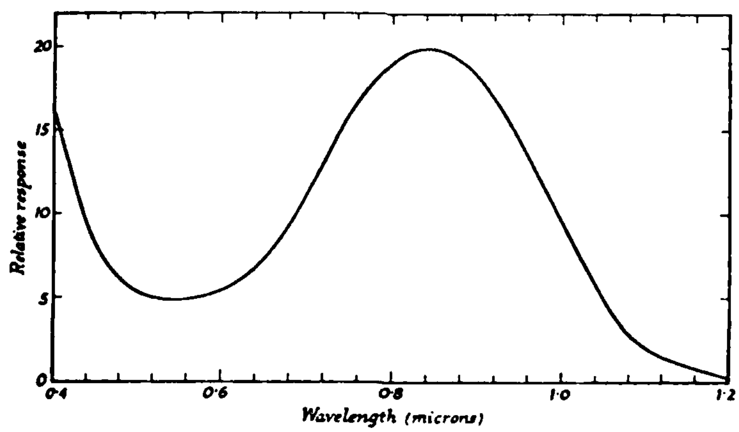

Fig. 2 — Relative Wavelength Response of the S-1 Photocathode

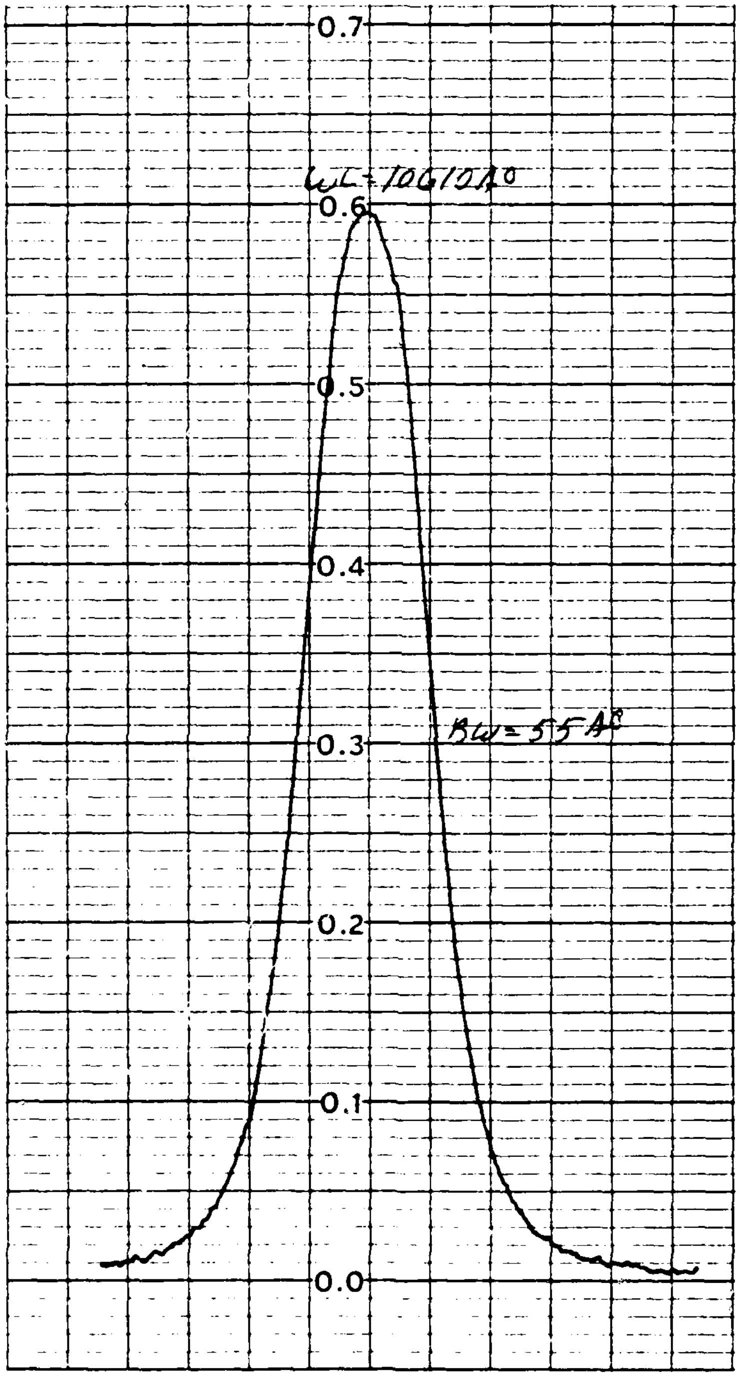

Fig. 3 — Spectrograph Trace of Narrow-Band-Pass Filter
Centered at 1.061 μm

A Biomation-8100 wave form recorder was used with an oscilloscope to effectively store the incoming signal. The Biomation-8100 was operated at 10 nsec per channel, 2048 channels, at an effective resolution of three channels per pulse width of 30 nsec. Since the LIDAR round-trip time is what matters, the effective range resolution of the system is 4.5 meters. Although further work needs to be done investigating the optimum bin size, if we assume 3 bins per pulse width of 30 nsec, we should be able to investigate ranges out to 2048 bins × 10 (nsec/bin) × 0.3 m/nsec × 1/2 or about 3 km. We were very pleased with the performance of this device and, we are now interfacing it to our HP-85 desk-top computer through the existing 16 parallel-line bus to provide multiple-pulse averaging, and background substraction. A Visicorder was used to display the result. In operation a reference detector, a silicon diode, was used to trigger the Biomation on the flashlamp pulse. The system diagram is shown in Fig. 4.

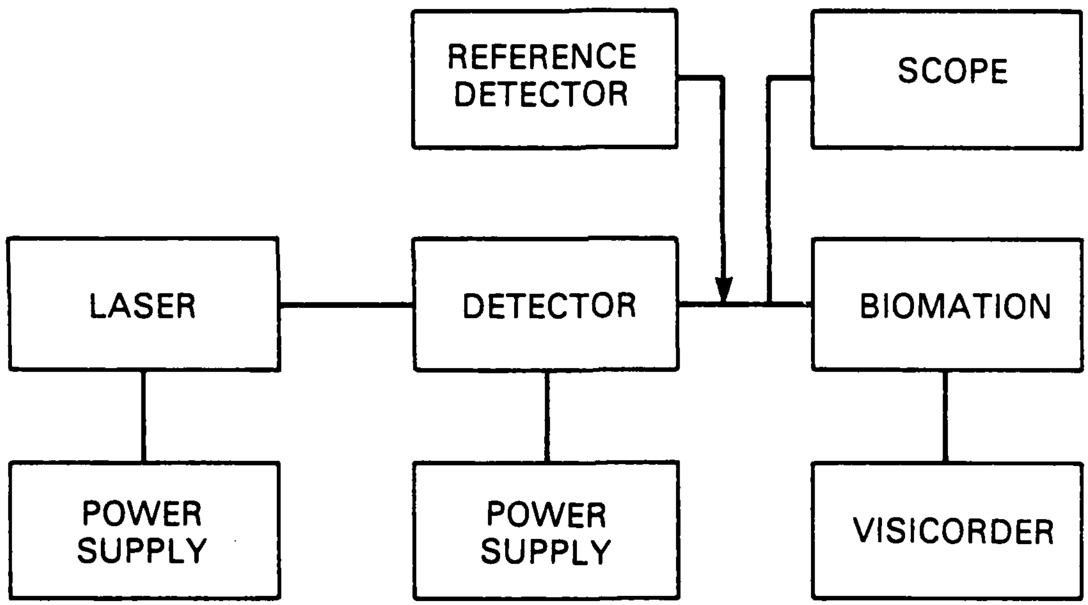

Fig. 4 — System Block Diagram

3. PROCEDURE

The experimental arrangement is shown in Fig. 5. The hard targets were: a white plywood sheet at 70 m, a white trailer at 600 m, and a woods line at about 700 m from the trailer housing the LIDAR equipment. The laser was aimed at each of the targets. Since the laser axis and telescope axis were separated by 50 cm, axial crossover for the bistatic system occurred at 35 m and 65 m for the near and far targets respectively. The plywood sheet (near target) reflectance was estimated at 1.0, and the

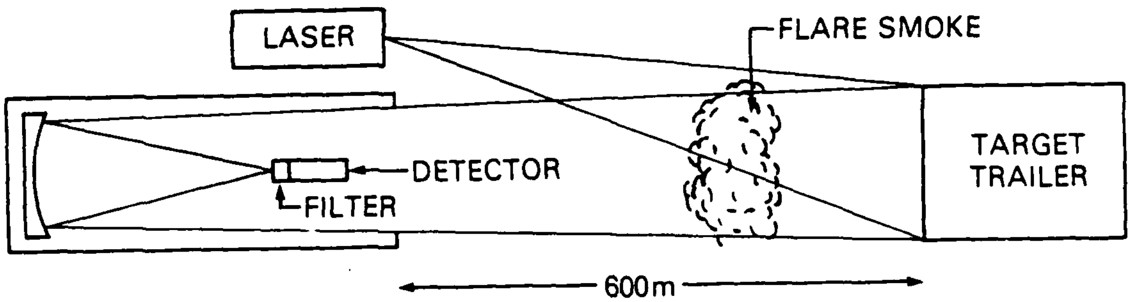

Fig. 5 — Experimental Set-Up

reflectance of the trailer doors (far target) was estimated to be 0.7. The reflectance geometry was similar at both distances. At 70 m the target area was larger than the laser beam cross-sectional area. (geometrical factor $G = 1$). At 600 m the target area to laser beam cross-sectional area ratio was $G = 0.35$. The atmospheric transmittance at 1.06 μm was estimated to be 1.0 for the near target, and 0.9 for the far target.

For the smoke backscatter investigation a pyrotechnic flare was ignited at about 450 meters. The white smoke was estimated to have as opacity (photopic) of about 50%. Part of the investigation was done during a mild rain, and backscatter from the rain was observed. The results reported in the next section represent data obtained from a single pulse. (The HP-85 interface will allow multiple pulse averaging for 1-10 Hz operation.)

4. HARD TARGET BACKSCATTER RESULTS

Figure 6 shows the chart recorder results for backscatter from the 600 m hard target with the smoke cloud evident at about 450 m, and a small signal from the surrounding trees at about 700 m. Equation (2) provides an approximate expression, derivable from Eq. (1), for the expected power received at the detector:

$$P \approx (5.3 \times 10^5 \text{ watts}) \times r \times G \times T \times \frac{0.2}{R^2}. \tag{2}$$

Where R is the range in meters, r is the target reflectance, G is the previously described beam-overlap geometric factor, and T is the atmospheric transmittance. In these preliminary measurements we did not attempt an absolute measurement of the return signal power, but using the above values we can compare the calculated vs measured *ratios* of the near and target signal levels. The 70 m signal was 6452, and the 600 m signal was 11.0; the units of both are the same chart recorder scale. Hence $\frac{P_{70}}{P_{600}}$ is measured to be 586, and Eq. (2) predicts:

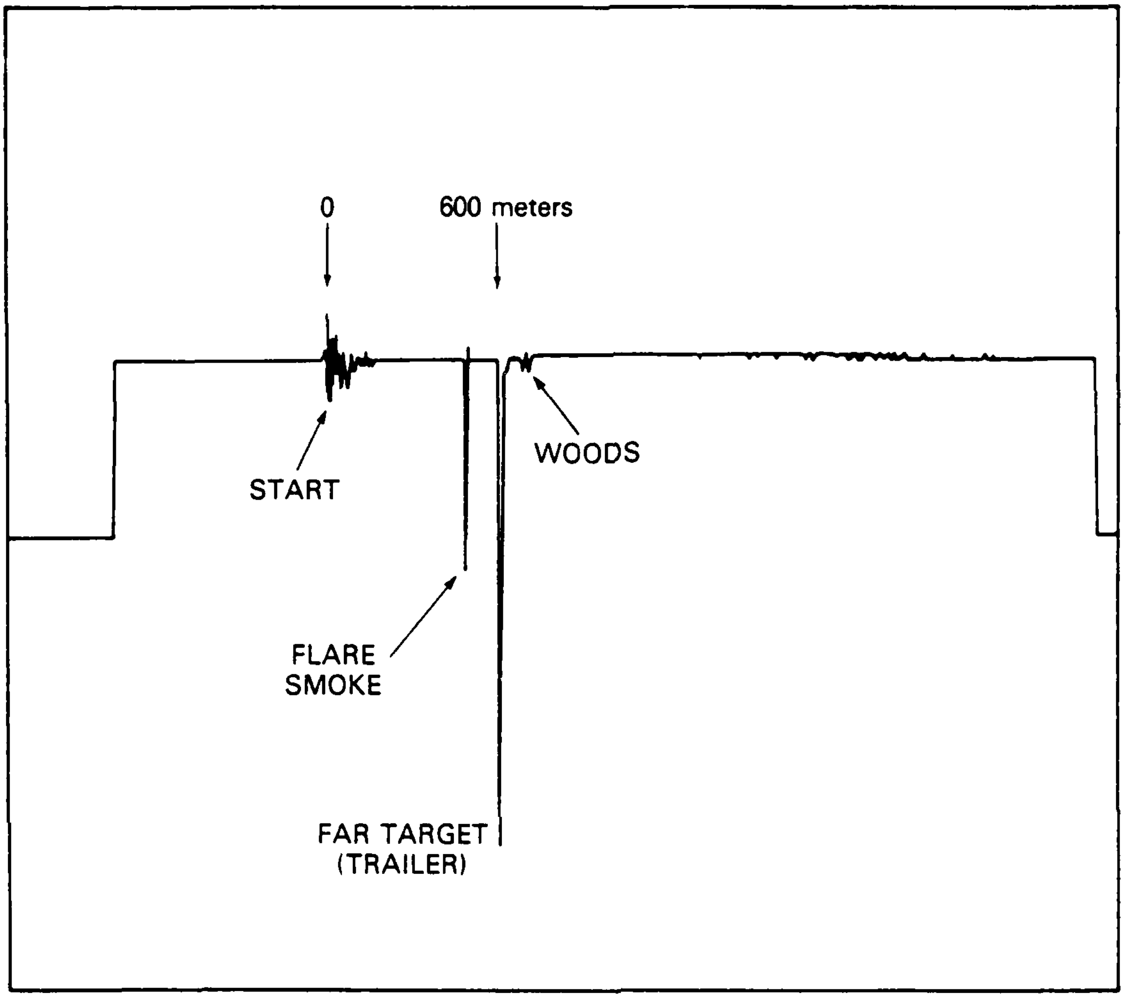

Fig. 6 — Backscatter From Two Fixed Targets and a Smoke Cloud

$$P_{70} = 21.6 \text{ watts}, \qquad P_{600} = 64.9 \text{ m watts}$$

or

$$\left(\frac{P_{70}}{P_{600}}\right)_{calc} = 333 \text{ vs } \left(\frac{P_{70}}{P_{600}}\right)_{meas} = 586.$$

We consider the fact that our measured and calculated results compare within 50% to be very encouraging considering the preliminary nature of this investigation.

5. AEROSOL BACKSCATTER RESULTS

Figure 6 displays a return signal for light smoke, at a range of about 450 m. The width of the return signal appears comparable to that of the hard-target return signal, i.e., about 10 meters range

resolution due to the laser pulse width. Unfortunately the signal gain in Fig. 6 was turned down very low so the entire hard-target backscatter signal would be recorded. But Fig. 7 shows the return signal from rain backscatter, even at the very low-gain electronic setting. Figure 7 also clearly shows the onset of a return aerosol backscatter signal at about 75 m, which is the bistatic cross-over distance. The expected $1/R^2$ signal decrease is also evident.

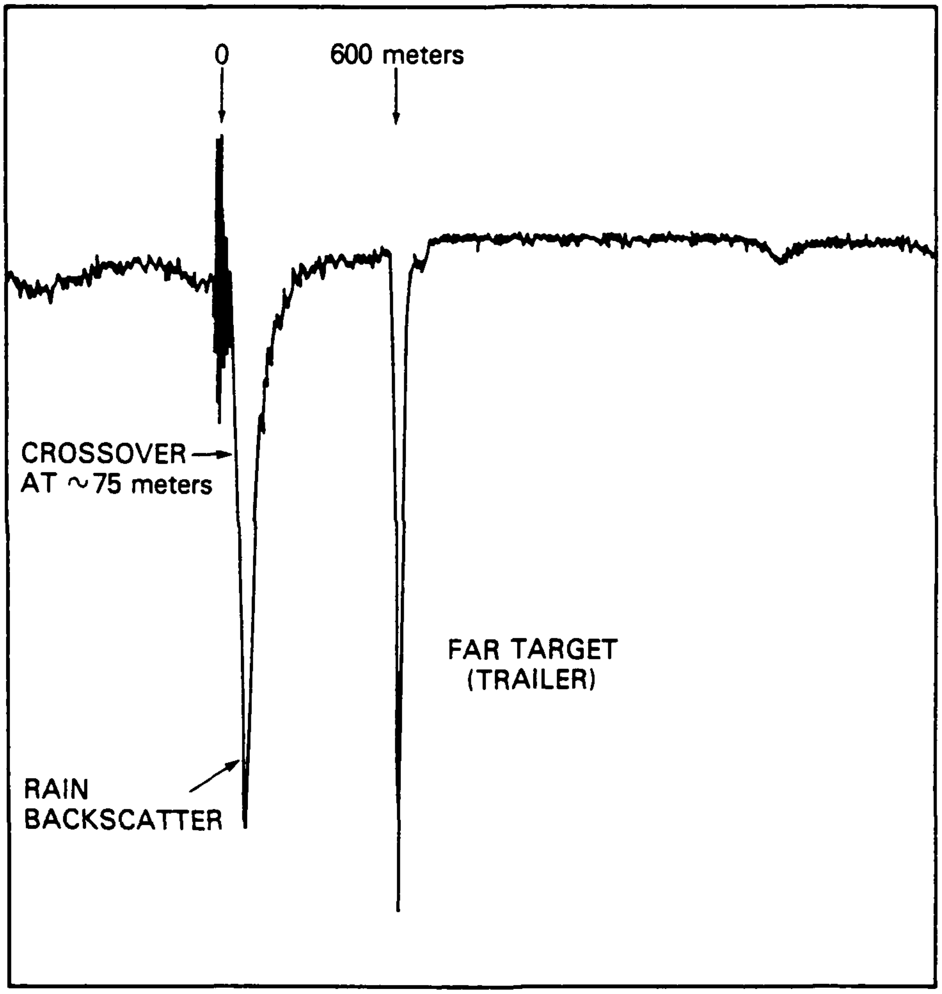

Fig. 7 — Backscatter from Rain

6. SUMMARY AND FUTURE WORK

The goal of this work was to assemble a LIDAR system and to obtain backscatter data from hard targets, and aerosols. This was successful, as evidenced by the order-of-magnitude agreement of our calculated and observed backscatter. We also obtained some aerosol backscatter data, and at relatively

low electronic gain we were able to see the expected signal turn-on at bistatic cross-over, and $1/R^2$ decay.

Our future work will concentrate totally on the aerosol backscatter problem. The Biomation-8100 will be interfaced to our HP-85 data system so multiple pulse averaging can be employed. The first aerosol backscatter problem we plan to analyze is the aerosol distribution around the surf at a beach. LIDAR signals will be compared in the simultaneous Knollenberg particle size distribution measurements using the NRL aerosol measurement equipment.[2]

Important contributions to this work were made by K. Haught, T. Royt, G. Stamm, and C. Acton.

7. REFERENCES

1. R.T.H. Collis, Applied Optics 9, 1782 (1970).

2. G.L. Trusty, and T.H. Cosden, "Optical Extinction Predictions from Measurements on the Open Sea," NRL Report 8260 (1979).

LMED

8